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Access to electricity in Small Island Developing States of the Pacific: Issues and challenges

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A R T I C L E I N F O

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A B S T R A C T

Energy poverty is widespread in Small Island Developing States (SIDS) of the Pacific. It is estimated that 70 percent of Pacific Islander households do not have access to electricity, which is equivalent to access rates in sub-Saharan Africa and slightly below the average for low income countries. Pacific SIDS face unique challenges in expanding access to electricity, given that their populations are spread across tens of thousands of islands. Governments and development partners in Pacific SIDS continue to prioritise development of electricity grids, as is evident in ongoing subsidisation of grid-based power consumption and the establishment of ambitious (grid-based) renewable energy targets.

This paper argues that traditional approaches to rural electrification which prioritise grid extension are not suited to the Pacific islands region. Increased funding should be directed by both governments and development partners towards rural electrification, especially in off-grid areas where isolated systems are more appropriate. Institutional reform is also important. Regulatory reform is needed for power utilities to extend electricity grids into rural areas. Institutional arrangements that facilitate the sustainable operation and maintenance of off-grid systems also need to be established. Past donor and government-funded off-grid rural electrification projects have rarely been sustainable. Alternative approaches involving payment of output-based subsidies to energy service companies are worth exploring, although will only succeed where sound regulatory arrangements are in place.

Contents

1. Introduction

Energy poverty, or the lack of access to modern energy services, is a significant global development challenge. Electricity facilitates economic activity and the delivery of key public services, including health, education and infrastructure services. Clean cooking

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technologies reduce the incidence of respiratory disease and enable women and children to spend less time searching for fuel wood. The Sustainable Energy for All Initiative, launched by UN Secretary General Ban Ki-Moon, highlights the need to increase access to modern energy services for the Millennium Development Goals to be achieved.

Energy poverty is widespread in Small Islands Developing States (SIDS) of the Pacific. It is estimated that 70 percent of households across the Pacific do not have access to electricity and 85 percent do not have access to clean cooking energy technology [1]. The vast majority of those households reside in rural areas. The figures are alarming. Energy poverty in the Pacific islands region is greater than in other parts of the Asia-Pacific, and is equivalent to that in sub-Saharan Africa, despite higher income levels.

The focus of this paper is on expanding access to electricity in Pacific SIDS. Pacific SIDS face unique challenges given the geography of the region. The population of 14 independent Pacific island states is spread across tens of thousands of islands, many of which are home to less than 100 people. Access to infrastructure, including electricity, is limited outside of urban centers. Traditional approaches to expanding access to electricity, which are focused on grid extension, are often not feasible in these areas. The reliance in rural areas on subsistence agriculture presents an additional barrier to rural electrification, given that it restricts the ability of households to pay for an electricity connection.

There is limited literature on access to electricity in SIDS of the Pacific. The region does not generally feature in international surveys, given its small population (see for example [2,3]). Reports on energy poverty and energy security from development partners are often general, with limited analysis of rural electrification policies [1,4]. Project documents, such as monitoring and evaluation reports, provide useful lessons at the project level, but given their narrow focus, provide less insight into broader policy questions associated with the allocation of scarce public resources. There is more literature available on renewable technologies in the region, however, it generally focuses on supply of electricity to the grid rather than off-grid areas [4–8]. Academic literature on rural electrification in Pacific SIDS is particularly sparse, being almost entirely focused on off-grid electrification projects using renewable technologies [9–12].

What is missing in the literature is a high level perspective on the challenges faced by Pacific SIDS in widening access to electricity. In particular, there has been no critical analysis of rural electrification policies across the Pacific islands region drawing on experience in the Pacific and other regions. The issue is of considerable importance given that progress in expanding access to electricity has been slow in the region. This paper addresses this gap in the literature.

2. Context

2.1. The challenge

The rate of access to electricity in SIDS of the Pacific is low by international standards, being equivalent to access rates in sub-Saharan Africa and slightly below the average for low income countries. There is nonetheless considerable variation in the electrification rates of different Pacific SIDS. Access to electricity is widespread in countries with relatively higher income levels such as Palau, Cook Islands, and Fiji.[1] In a number of micro-states all households have access to electricity, such as in Nauru, a single island state with a population of 10,000 (see Table 1). Energy poverty in the region is concentrated in three countries: Papua New Guinea (PNG); Solomon Islands and Vanuatu. These countries account for 84 percent of the population of all 14 independent SIDS in the Pacific, and have very low levels of access to electricity. The electrification rate in all three countries is lower than that of other countries with similar levels of GDP per capita (see Fig. 1).

The challenge faced by policy makers in widening access to electricity in Pacific SIDS is significant. The vast majority of unelectrified households in SIDS of the Pacific reside in rural areas, justifying a focus on rural electrification (households in informal urban settlements comprise only a small proportion of households without access to electricity). Households in rural areas are commonly distant from electricity grids. Connecting these households to an electricity grid is not financially feasible, given low levels of demand, low population density, and geographical constraints (such as archipelagos of islands) (see Fig. 2). Off-grid electrification is more feasible, but involves significant upfront costs for households. These upfront costs are often beyond the capacity of rural households to fund, given lack of cash income and available credit.[2]

The case of the Solomon Islands illustrates the challenges faced in the region. The Solomon Islands has an estimated population of 552,000 spread across more than 900 islands. Electricity grids are in place in only several urban centers, with little access to electricity outside of these townships. Approximately 12 percent of Solomon Islanders have a power supply, with access to electricity in rural areas estimated at 4 percent [14,15]. The average cash income in Solomon Islands is US$1515, but incomes in rural areas are considerably lower, with rural households generally reliant on subsistence agriculture for livelihoods. Non-cash livelihoods limit the ability of rural Solomon Islanders to purchase off-grid systems or fund grid extensions. The ability of the government to invest in infrastructure is also restricted, given fiscal constraints. Government spending on rural electrification in 2012 totalled just US$1.34 million (this represented an increase on previous years) [16].

2.2. Impact

The lack of access to electricity in Pacific SIDS produces adverse economic and social impacts. It is widely acknowledged that access to electricity is welfare enhancing, although evaluation can be difficult due to attribution problems [17]. Electricity facilitates economic activity and the provision of a range of basic services. It enables cold storage of food and vaccinations, and is essential for use of appliances such as computers, televisions, radios, and mobile phones. Electronic appliances are often important sources of information for rural households, and in many SIDS are leading to greater access to formal financial services in rural areas. The use of electricity for lighting extends working hours, makes public spaces safer, and permits children to do homework at night [8,18]. It has also been demonstrated around the world that the provision of electricity helps attract teachers and healthcare workers to rural areas [3]. A recent survey of health and education facilities in rural areas of Papua New Guinea supports these findings [19,20].

Access to electricity has financial advantages. Electricity replaces expensive traditional fuels such as kerosene for lighting

[1] There is a statistically significant relationship between log GDP per capita and access to electricity. A comparison of electrification rates in Africa, Latin America and Asia in [13] demonstrates that low population densities result in access to electricity being below what would be expected for a given level of per capita GDP. This also appears to hold true for Pacific SIDS.

[2] Land is the only significant financial asset owned by most rural Pacific Islanders, but ownership is vested in communal structures which prohibit its use as collateral.

and use of batteries to power radios and other small appliances. Households with access to electricity therefore spend less money on energy than comparable households without access to power, although upfront costs associated with electricity connections are often unaffordable for rural households. The financial benefits of access to electricity are true for both households connected to the grid and those connected to off-grid systems [1,18,21,22].

Table 1
Access to electricity in Small Island Developing States of the Pacific.Source: [14–24].

Small Island Developing States of the Pacific	Access to power (percent)	Population	GDP per capita (2011 USD)
Low levels of access			
Papua New Guinea	10	7,013,829	1794
Solomon Islands	14	552,267	1517
Vanuatu	17	245,619	3167
Sub-total		7,811,715	
Medium levels of access			
Federated States of Micronesia	54	111,542	2854
Kiribati	63	101,093	1803
Republic of Marshall Islands	80	54,816	3448
Fiji	89	868,406	4390
Sub-total		1,135,857	
High levels of access			
Tonga	95	104,509	4335
Cook Islands	99	20,414	13,478
Samoa	99	183,874	3629
Palau	97	20,609	11,096
Tuvalu	100	9847	3712
Nauru	100	10,308	6954
Niue	100	1400	-
Sub-total		350,961	
The region compared			
Pacific SIDS	30		
Low income	31		
Lower-middle income	82		
Upper-middle income	87		
Developing countries	58		

Financial benefits associated with access to electricity are observed in Pacific SIDS. In Fiji, a number of surveys have found that un-electrified households spend more on energy for lighting than electrified households [23–25]. A 2009 study of communities in northern Fiji established that un-electrified households spent more on energy than households that were connected to an off-grid system (both solar home systems and village diesel generators were surveyed). These un-electrified households were also more vulnerable to increases in the price of fuel, as shown in Fig. 3.

2.3. *Renewable energy*

Pacific SIDS in recent years have sought to utilise renewable energy resources in order to lessen exposure to oil price volatility and address climate change [4,5,26]. The focus of efforts has been in the power sector. All independent SIDS in the Pacific have established renewable energy targets with the exception of Papua New Guinea (see Table 2). The targets adopted by Pacific SIDS are among the most ambitious in the world. They reflect a high level of awareness about, and extreme vulnerability to, climate change; although mitigation efforts are largely symbolic given the small scale of emissions from the Pacific (whether they bolster the negotiating position of Pacific SIDS in international climate change discussions is open to debate). Targets also reflect the availability of considerable funding from development partners for renewable energy technologies.

The ambitious renewable energy targets established by SIDS in the Pacific present both opportunities and risks for widening access to electricity. Given geography and population distribution, expanding access to electricity is likely to require greater investment in off-grid systems in Pacific SIDS than in other developing countries (with the exception of parts of sub-Saharan Africa, where off-grid options are also important [27]). Off-grid electrification is often considered a "niche" area to which certain renewable technologies are especially suited. The use of renewable technologies for rural electrification is cost-competitive on a lifecycle basis with conventional technologies [28]. In Pacific SIDS, a number of cost–benefit analyses have found that lifecycle costs of solar and micro-hydro technologies are equivalent to those of small diesel or petrol systems [26,29]. Use of renewable technologies for off-grid electrification is especially suited to remote areas

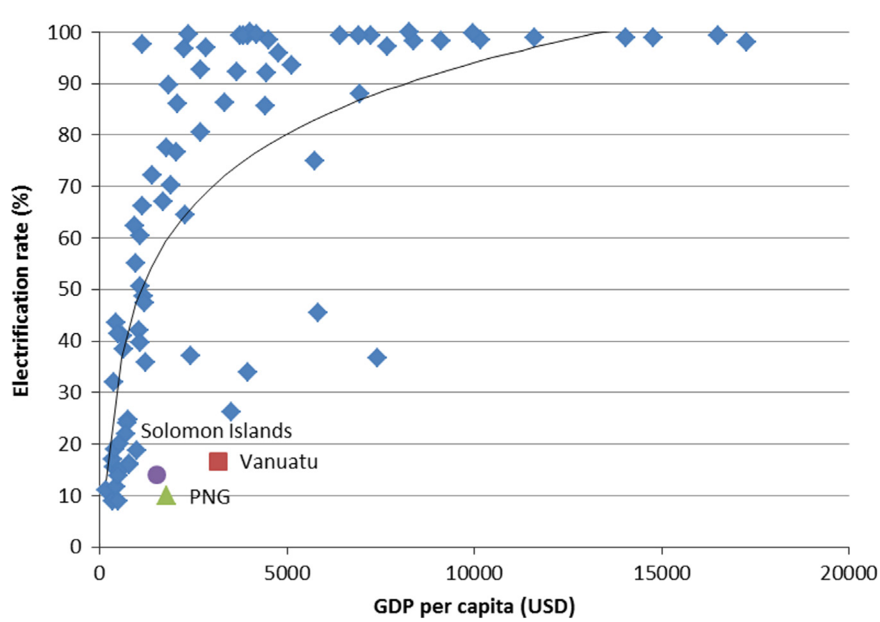


Fig. 1. Access to electricity and GDP per capita. Note: Power supply may be from off-grid or grid sources, and may not be a 24 h supply. *Source*: [14–24]

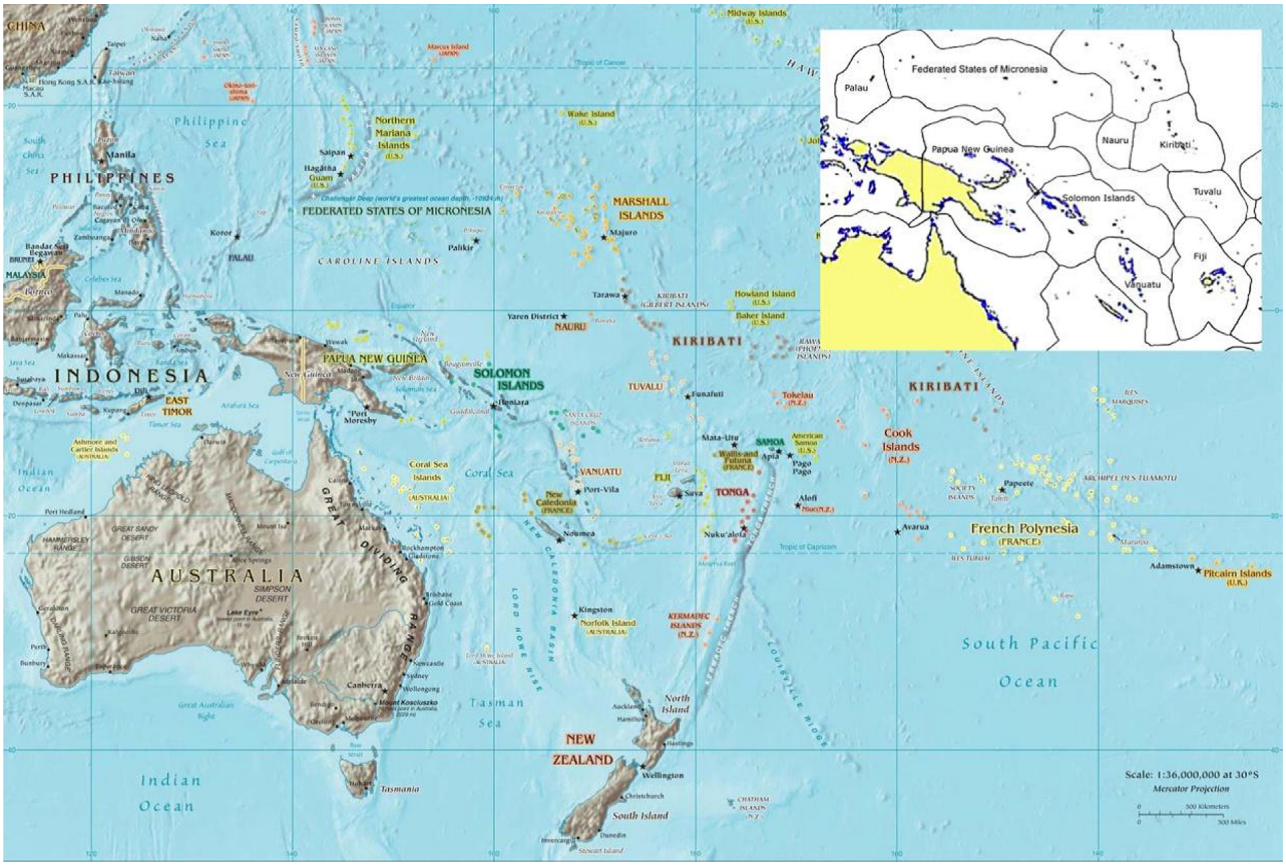


Fig. 2. Map of the Pacific islands region.

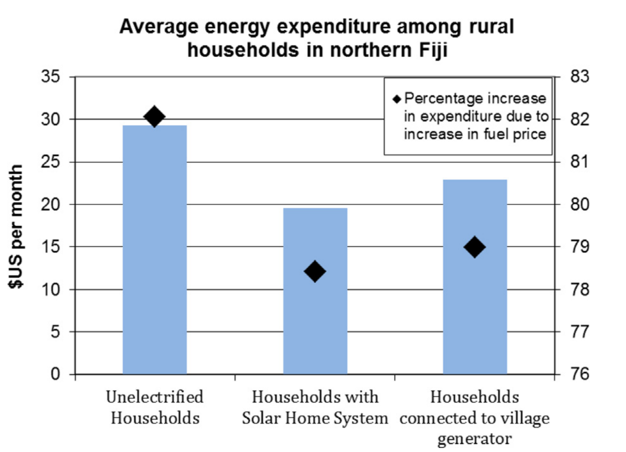


Fig. 3. Impact of fuel price increases (2005–2008) on energy expenditure among households with different electrification technologies.
Source: [35]

Table 2
Renewable energy targets among Small Island Developing States in the Pacific. Source: [15,20,21,36,37].

Country	Target[a] (percent)	Target date	Current renewable share of power generation (percent)
Cook Islands	100	2020	0
Fiji	90	2015	45
Kiribati	28[c]	2025	0
Marshall Islands	20	2020	0
FSM	30	2020	28
Nauru	50	2015	0
Niue	100	2020	0
Papua New Guinea	No target in place		Over 40
Palau	20[b]	2020	12
Samoa	10[b]	2016	30–40
Solomon Islands	20[b]	2020	0
Tonga	50	2020	4
Tuvalu	100	2020	5
Vanuatu	65[b]	2020	15

[a] Targets refer to percent of electricity supply, unless otherwise indicated.
[b] Target refers to primary energy supply.
[c] This is a weighted average of two targets: 23 percent (Tarawa island), and 60 percent (Kiritimati island).

where there is infrequent supply of fuel, as is the case in rural areas of the Pacific islands region [10,26].

However, ambitious renewable energy targets also generate risks for rural electrification. Pacific SIDS, in order to meet these targets, will require substantial investment in renewable technologies. The bulk of this investment will be in areas where there is already access to electricity. Rural electrification will have only a very minor impact on enabling countries to meet renewable energy targets, given low levels of demand for power in underdeveloped rural areas. There is therefore the potential for renewable energy targets to divert attention and funding of governments and development partners away from rural electrification.

There are already indications that this is occurring. At the Pacific Energy Summit in March 2013, governments of Pacific SIDS provided a list of current and proposed projects in the energy sector. The list is not a comprehensive overview of spending in the energy sector, but it does indicate projects for which Pacific SIDS seek funding, and therefore provides insight into the priorities of governments. Projects that focus on expanding access to modern

energy services (including electricity) account for 4 percent (US $12.9 million) of the total value of projects on the list (US$761.4 million). The vast majority of projects involve power generation for the grid using renewable technologies.

3. Expanding access to electricity

Electricity in Pacific SIDS is currently provided in various forms. State-owned power utilities generally supply electricity to one or more electricity grids. These grids are confined to urban and peri-urban areas, although in some countries they extend into rural areas (e.g., Fiji and Samoa).[3] Rural households are also supplied by small off-grid systems. These systems can be installed privately or with government funding, and provide power to a village or household using a petrol or diesel generator, or a solar home system.[4] Power is normally supplied from off-grid systems for only several hours each day.

Expanding access to electricity in Pacific SIDS will involve both extension of existing electricity grids and installation of off-grid systems. Challenges to rural electrification using both approaches are discussed below.

3.1. Extension of electricity grids

In many Pacific SIDS there is scope to extend electricity grids from urban centers into surrounding rural and peri-urban areas. This is especially true for the populous Melanesian states which have low levels of access to electricity (PNG, Solomon Islands, and Vanuatu). Grid-based supply of electricity is generally favoured by households, given the more reliable supply of power 24-h per day (this is confirmed by a number of surveys, such as [23–25]).

The high upfront cost associated with grid extension means that subsidisation is generally required. Subsidies can take many forms, and can be provided by governments or development partners. The most common form of subsidy used in Pacific SIDS is a cost sharing arrangement, where governments (or development partners) pay a proportion of the cost of grid extension. Power utilities and households connected to the grid generally also contribute. Subsidies for rural electrification can be significant. In the case of Fiji, the government pays 95 percent of the cost of rural electrification and households pay the remaining 5 percent. This payment is not means tested, meaning that high-income households also benefit from the subsidy. The waiting lists for accessing such subsidies are very long.

The provision of a one-off subsidy to address the high upfront cost of electrification is effective only under certain conditions. The power utility must be able to generate a profit from new connections if it is to have a commercial incentive to extend the grid [30]. This requires that the electricity tariff paid by newly connected households is higher than the ongoing cost of supply (less any government subsidy for connection).

The condition is often not met in countries where rates of access to electricity remain low. A recent benchmarking survey of Pacific power utilities suggests that there are six utilities that make a loss on every unit of power that they sell [31].[5] This mirrors the situation in sub-Saharan Africa, where negative financial returns among vertically-integrated state-owned power utilities are common [32,33]. Low electricity tariffs resulting from political imperatives adversely affect the performance of state-owned utilities, which are unable to invest in maintenance, generation capacity, or extension of electricity grids [34–36].

One way to address this issue is to establish a regulatory body to set prices independently of government. Evidence from Pacific SIDS suggests that utilities operating under independent price regulation are more likely to generate a profit, and perform better, than utilities operating where prices are set by government (whether directly, or through government influence over utility management/boards). The benchmarking survey of Pacific power utilities found that this was the case whether the utility was state-owned or a private company, as shown in Fig. 4.

Many power utilities in Pacific SIDS receive government subsidies. These can take the form of *ad hoc* payments used to support power utilities in financial distress, or government assistance for major expenditure (such as periodic maintenance of the distribution network). Power utilities in the Pacific are rarely obliged to extend the grid to new areas in order to access these subsidies. Only two Pacific utilities have in place a service obligation to rural areas near the grid [31]. Electricity sector legislation instead requires utilities to serve paying customers already connected to the grid, meaning that operating subsidies are directed towards existing customers, not grid extension.

The provision of ongoing subsidies in Pacific SIDS presents a drain on government finances and generally fails to target low-income households. The fiscal cost of ongoing subsidies means that there are fewer resources available for new connections to the grid, or for rural electrification using off-grid technologies [37]. This is an issue in many Pacific SIDS. In Solomon Islands for example, state support for the power utility far exceeds the rural electrification budget [16,38]. In Fiji, the state does not provide explicit subsidies, but it does provide tax breaks and guarantees loans to the utility for renewable energy projects [39,40]. These implicit subsidies exceed spending on rural electrification [41]. The Fiji example demonstrates a common issue faced by Pacific SIDS: competition between the priorities of achieving ambitious renewable technology targets and expanding access to electricity.

Regulatory arrangements in the electricity sector affect electrification in other ways. Electricity utilities around the world often charge a uniform tariff for power, despite the fact that the cost of supply varies between different areas [35,42]. The practice of cross-subsidisation is motivated by equity objectives. Urban centers, where demand for power is highly concentrated, are normally profitable for the utility and are used to cross-subsidise loss-making rural areas, where demand is less concentrated and transmission and distribution losses are higher [30,34].

Cross-subsidisation has the effect of limiting the extension of electricity grids into rural areas. Although electricity tariffs may be higher than the average cost of supply, and a power utility may be profitable, the cost for the utility of supplying a *rural household* may exceed the uniform tariff rate. A number of studies in sub-Saharan Africa have shown that a uniform tariff has acted as a disincentive for rural electrification by power utilities, which consequently focus their operations on urban areas [32,33,43]. This is also true for the majority of power utilities in the Pacific [40,44,45]. In Fiji for example, urban operations in the greater-Suva area were used until recently to fund electricity provision to the rest of Fiji [46]. Papua New Guinea's Electricity Industry Policy notes that uniform tariffs result in a situation where: "The higher cost areas of investments, especially *rural areas, have been effectively neglected of the provision of vital electricity service as a consequence*" (italics added) [45].

Lifeline tariffs are another constraint to rural electrification in Pacific SIDS. Lifeline tariffs are a sensible policy used to provide (primarily) low-income households with an affordable electricity

[3] In areas removed from the main grid, a small number of households are supplied by mini-grid systems that supply highly subsidised electricity to hospitals, schools, and police stations in rural government centers.

[4] Other technologies are used less commonly, such as micro-hydro power schemes or wind turbines.

[5] This data are supplemented by statistics provided in the National Infrastructure Investment Plans of five Pacific island countries (available at ⟨http://www.theprif.org⟩).

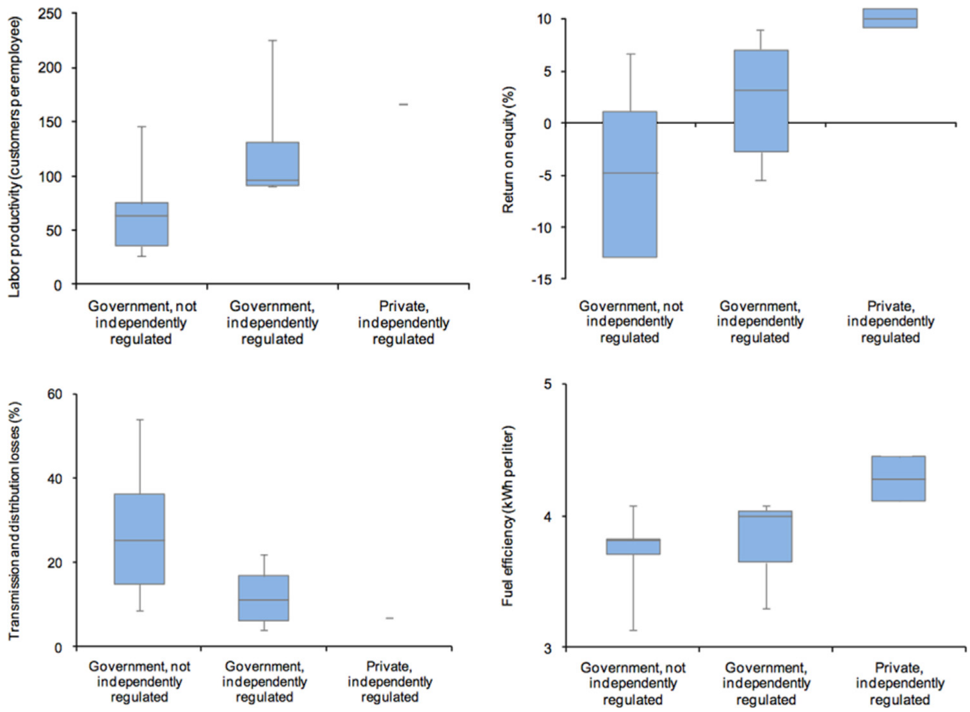


Fig. 4. Performance of power utilities in Pacific SIDS.
Source: [45]

supply by charging less for low levels of power consumption. Their use is increasing in Pacific SIDS, given concerns about affordability where state-owned utilities are corporatised, and the absence of social welfare systems [31]. However, lifeline tariffs can have unintended implications for extension of the grid. Households without access to the grid (which are primarily rural) have low incomes on average, meaning that they are more likely to pay lifeline tariffs than households in urban areas. The result is that the average tariff received by the utility in rural areas is also lower. This can make rural electrification commercially unattractive for power utilities where governments do not reimburse lifeline tariffs, as is common in Pacific SIDS.

3.2. *Off-grid electrification*

The geography and population distribution of Pacific SIDS makes the installation of off-grid systems an important element of rural electrification. This presents both opportunities and challenges for policy makers seeking to expand access to electricity. In areas of low population density, the upfront cost of off-grid systems is normally lower than extension of the grid. Modelling exercises have shown this to be the case for much of rural sub-Saharan Africa [27]. It is also true in most rural areas of Pacific SIDS. A review of the rural electrification program in Fiji found that the average cost per connection for grid extensions was almost four times that of installing an off-grid diesel-fuelled generator [47]. The cost of electrification through the installation of off-grid systems is therefore lower for Pacific SIDS than would be the case if electricity grids were extended to all households.

However, the focus on off-grid electrification also presents challenges. The operation and maintenance of off-grid systems has historically been problematic, both in Pacific SIDS and other developing countries. There are many examples of off-grid rural electrification projects that have not proven sustainable. In Thailand, the government sponsored solar-charging program failed due to poor operation and maintenance of equipment at the village level [48]. In South Africa, financial constraints led to low take-up of an NGO and government-sponsored solar home systems program in the 1990s (lack of capacity for maintenance was later an issue for systems that were installed) [49]. In Zimbabwe, local solar-PV enterprises established with support from donors failed when external funding ceased [50]. A clear lesson from these and other case studies is that sound institutional arrangements are crucial for ensuring that off-grid electrification is sustainable [51–55].

In Pacific SIDS, off-grid electrification has proceeded through a combination of cash sales and government/donor-funded rural electrification programs. Cash sales of off-grid systems are common in countries where commercial agriculture is more developed. The Fiji census reveals that 5 percent of households access electricity using privately-purchased off-grid systems, almost as many as those connected to village diesel generators installed with government subsidies [56].

Cash sales of conventional technologies have been more successful than sales of renewable technologies. This is due to higher upfront costs and lack of familiarity with new technologies [50,57,58].[6] Some renewable technologies have also developed a bad reputation due to (i) limited after sales service, and (ii) installation of poor quality products, resulting from customer incentives to reduce the upfront cost, and lax or non-existent regulations governing the quality of system components [53,58].[7]

Although cash sales have been significant in some countries, the upfront cost of off-grid systems presents a barrier to widespread electrification without the use of subsidies. Only high

[6] To illustrate, the upfront cost of off-grid solar home systems installed as part of Fiji's *Rural Electrification Policy* in 2009 was FJ$4065 compared to FJ$2737 for village-based diesel generators. The upfront costs of such renewable technologies are likely to be considerably lower in the future given technological progress.

[7] Limited knowledge of photovoltaic technology among consumers exacerbates these problems. In Kiribati for example, solar home systems sold in the 1980s failed due to the purchase of undersized systems with cheap replacement components, and unwillingness among customers to pay for maintenance. The company that sold the systems went bankrupt as a result.

income households in rural areas of Pacific SIDS have the financial resources or access to capital to purchase off-grid systems. The barrier presented by upfront costs is especially pronounced for renewable technologies such as solar systems, which have a high upfront (or capital) cost but low operating and maintenance costs [26,59,60].

Market failures associated with lack of access to credit and imperfect information provide the context for rural electrification programs funded by government and development partners. The most common off-grid approaches adopted in rural electrification programs involve (i) the donation (or heavy subsidisation) of off-grid systems, and/or (ii) the provision of credit to rural households. Sustainability has been a problem for both approaches, with rural electrification using renewable technologies especially problematic. Early failures of off-grid renewable energy projects in Pacific SIDS were due mainly to technical problems with untested equipment. Failures in the last two decades, however, have been more the result of inadequate institutional arrangements for operation and maintenance, which have also afflicted projects that use conventional (non-renewable) technologies [7,52,55,61,62].

The failure of early donation/credit models has focused attention toward project sustainability. The provision of systems and credit by governments or development partners is now generally complemented by various forms of institutional support and training [30,54]. These efforts have achieved mixed success. Building the capacity of rural communities to maintain off-grid systems through training has in many cases borne only temporary results. Common challenges to community-based maintenance in Pacific SIDS include the migration of technicians away from rural communities (often to find employment in urban areas using their new skills), and the failure of rural communities to set aside appropriate funds for periodic maintenance (such as battery replacement) [54,55]. Responses to these challenges such as use of prepayment meters and payment of local technicians have also achieved mixed success, with continuing migration of technicians away from rural areas and pervasive tampering of off-grid systems.

Some critics argue that support from development partners and governments has not been adequate or sustained [11]. In Tonga for example, past solar-based rural electrification projects in outer islands have dedicated only 2 percent of project funding towards institutional support and training [11,12]. These arguments downplay the significant resources necessary to ensure ongoing support for rural electrification projects. Governments in Pacific SIDS have limited capacity to ensure sustainability of rural electrification programs. Resource constraints mean that government provision of maintenance has generally only been viable for pilot projects.[8] The Fiji Government's ongoing support for diesel generators installed before 1993 is a case in point; the policy of subsidised maintenance was discontinued as more systems were installed. The quality of government support also depends on whether adequate funding is provided to the responsible agency. Budget allocations to implementing government departments and agencies are often uncertain [36]. Governments in SIDS of the Pacific commonly prioritise new infrastructure over maintenance of existing infrastructure [36].

Another criticism levelled at rural electrification projects involving donation of systems is that they have hindered the organic development of energy businesses through government or donor provision of off-grid systems below cost. This criticism is especially relevant to renewable technology projects, which affect a nascent industry, are more heavily subsidised, and are more likely to involve the supply of generation equipment made overseas [48,50,63]. Development partners are in response increasingly focused on using the private sector for rural electrification [50,57,63]. However, attracting private sector investment in rural electrification is a challenge. Private sector investors face significant risk in rural areas of Pacific SIDS, due to weak judicial systems, unreliable infrastructure (affecting access to schemes), and customary ownership of land. Government provision of subsidies, which is required to attract private sector operators to cash-poor rural areas, creates additional uncertainty due to lack of government capacity and political instability in larger Pacific SIDS.

4. Addressing the challenge

Expanding access to electricity to the majority of Pacific Islanders is a considerable challenge. It requires allocation of financial resources by governments and development partners operating in Pacific SIDS. The requisite financial resources are significant but not beyond the capacity of governments and development partners to deliver over the long-term. The capital cost of providing all un-electrified households in Fiji with access to power using off-grid systems is estimated at approximately US$35 million, which spread over a 10 year period would amount to 0.3 percent of government revenue each year [26]. The cost in countries with a bigger un-electrified population is larger, of course. Similar estimates for Papua New Guinea and Solomon Islands would result in spending of approximately 2 percent of GDP over a 10 year period (this amount is higher if considering extension of the grid). Over a longer timeframe (20 years), and with the financial support of development partners, the provision of these levels of funding is not impossible.[9] The continuation of high levels of economic growth enjoyed recently in these resource-rich countries will help address funding constraints to rural electrification.

Political will is needed to allocate resources towards rural electrification. Governments in Pacific SIDS direct very low levels of funding towards rural electrification, while at the same time subsidising power consumption among existing electricity consumers. Government subsidisation of investment in renewable technologies is one example of prioritising existing (mainly urban) electricity consumers over un-electrified rural households. Governments in Pacific SIDS also direct fewer resources towards off-grid electrification than extension of the grid.[10] There is to some extent a trade-off between the two; extension of the grid leaves less funding available for off-grid electrification. The economic and social impact is also different. On average, extension of the grid produces greater economic benefits, but off-grid electrification targets households with lower incomes [8,18].

4.1. Output-based approaches to rural electrification

Governments can potentially minimise the fiscal burden associated with rural electrification by using subsidies to leverage private sector investment. One approach to rural electrification adopted in other regions has involved the use of output-based subsidies, where concessionaires are awarded for electrification of

[8] Two solar-based pilot programs implemented in Fiji in the 1990s continued to function with government support for many years, however the programs were heavily subsidised and could not be repeated at a nationwide level [59].

[9] These calculations are very approximate estimates only, based on electrification costs for Fijian households provided by the Fiji Department of Energy, and assuming an average household size of 4.75 across countries. The estimates are included here only for illustrative purposes.

[10] In Fiji for example, between 1990 and 2008, 62 percent of rural electrification projects involved grid extension. These projects on average involved many more people than off-grid installations, meaning that the percentage of households that received grid extension was higher still (data at the households level were not available) [67–70].

rural households (including low income households) in a predetermined area [64–66]. Concessionaires can be private sector utilities, as is common in Latin America, or cooperatives such as in Bangladesh or Botswana [32,67].

Two countries where the output-based approach has been especially successful are Argentina and Chile. In Argentina, the government developed concessions in the north-west of the country which led to the electrification of 11,500 households and 1600 public buildings between 2001 and 2011. The approach was even more successful in Chile, where from 1994 the Chilean Government awarded one-off subsidies for rural electrification to private sector companies through a competitive process. Access to electricity in rural areas increased rapidly as a result, from approximately 50 percent in the early 1990s to over 96 percent in 2006 [30]. The use of output-based subsidies was also successful in leveraging private sector investment. Between 1994 and 1999, the Chilean Government paid subsidies worth US$112 m (65 percent of total costs) while private operators invested US$60 m (35 percent) [64].

The use of output-based approaches for rural electrification has been limited in SIDS of the Pacific. One output-based approach that has been used for off-grid rural electrification in several Pacific SIDS is a user-pays arrangement, where an Energy Service Company (ESCO) provides ongoing technical support to households. This fee-for-service arrangement differs considerably to the government and donor-funded off-grid rural electrification programs described in the previous sections. It has much in common with the arrangements for off-grid electrification in Argentina and Chile: a private company supplies electricity in return for payment from users and government.

The ESCO arrangement is most common for solar-based rural electrification, and has achieved some success in Africa. In Zambia for example, ESCOs that were formed with donor support have continued to maintain solar home systems even after external funding ceased [60]. In Kenya, ESCOs are now operating within a larger solar market which has thrived since donors assisted with its establishment in the 1990s [50,68]. ESCO arrangements can also supply electricity using conventional technologies. In Brazil, power utilities supply electricity to remote communities using diesel generators.

ESCO arrangements have been trialled in Pacific SIDS. In Kiribati, the Solar Energy Company used donor-funding in order to deliver solar home systems at a low price to customers for many years [54,69]. A more extensive program was implemented in Fiji. In that scheme, funding from development partners was used by the Fiji Department of Energy to purchase and install solar home systems in several thousand rural households. Households were charged a monthly fee of US$7.42 for these systems, which remained the property of the government. The Fiji Department of Energy used these funds to purchase equipment and pay an ESCO to maintain the systems. However, the user fee was not sufficient for these activities; the program required ongoing subsidisation from government.

The Renewable Energy Service Company (RESCO) program in Fiji achieved mixed results. The program has proven very popular given low fees and upfront costs. However, a small survey of households participating in the program in 2009 found that on average, technical problems resulted in power outages for 32 percent of the time over a 2 year period [10]. This can be explained by poor design of the program rather than a fundamental problem with the ESCO model. The ESCO was paid by the Department of Energy regardless of whether rural households paid their monthly fee, thereby removing the commercial incentive of the ESCO to ensure systems functioned. Penalties levied on the ESCO where systems did not function were also ineffective, given that system performance across a large geographical area was beyond the capacity of the Department of Energy to monitor.

Experience in Pacific SIDS with ESCO programs point to challenges in establishing effective output-based approaches for rural electrification. Private sector concessionaires are motivated by commercial considerations, meaning that they have incentives to extend the grid to profitable areas rather than areas where need is greatest [70]. The design of output-based subsidies and concessions that provide the private sector with appropriate incentives is therefore important.

It is evident that in Fiji and Kiribati appropriate incentives were not established for private sector ESCOs. In both cases, sub-optimal maintenance led to the failure of installed systems. Neither did the programs sufficiently consider consumer demand. The one-size-fits-all approach adopted in both countries led to dissatisfaction among higher income households, many of which tampered with systems designed only for lighting in order to power appliances (e.g., televisions). This ultimately reduced system life. Payment methods were also unsatisfactory. In Fiji, some households were forced to travel long distances in order to pay for the monthly code used to activate their solar system [10,23,71,72].

This contrasts with the successful programs in Chile and Argentina, where concessions were granted on the basis of multiple criteria, including cost–benefit analysis, commitment to invest, and social impact. The cost–benefit focus ensured that subsidies were required only for initial connection costs, with companies required to show that they could subsequently make a profit through the continued supply of electricity. The inclusion of social impact in the selection criteria encouraged private companies to work closely with community groups when preparing bids, and ensured that low income households were included in project design. These successful cases provide lessons for Pacific SIDS.

4.2. *Reform in Pacific SIDS*

Institutional constraints to rural electrification need to be addressed in order to expand access to electricity in Pacific SIDS. Appropriate government frameworks that guide rural electrification investment are necessary. In Pacific SIDS, high level policy frameworks are often incomplete, with vague undertakings that fail to establish targets for rural electrification. In other cases, national development plans establish unrealistic targets for rural electrification with no detail on how those targets are to be met. Resourcing is also a problem; budget allocations for rural electrification are commonly below what is promised in national development plans, and often neglect maintenance of existing off-grid systems. This reflects a broader disconnect between national development plans and sectoral budget allocations in Pacific SIDS.

Such issues need to be addressed in order to widen access to electricity in the Pacific islands region. Realistic government commitments, targets and associated plans are necessary, and must be matched with adequate resourcing and policy reform. National planning should also articulate respective roles for grid extension and off-grid electrification in expanding access to electricity. This will help ensure that adequate funding is provided in each area.

A number of reforms are necessary for the extension of electricity grids in Pacific SIDS. Power utilities must be provided with incentives and resources to extend electricity grids. Establishing incentives requires a revision of electricity tariffs and subsidies to address the problems outlined in Section 3.1. It also means making managers accountable for the performance of power utilities. Political barriers to such reforms are significant, as evident in the reform experience of a number of Pacific SIDS [73]. Political leadership is required to balance the needs of households that are connected to the electricity grid with those that are not, and to ensure that subsidies are affordable and target low income households.

Experience suggests that the establishment of independent regulatory bodies provides a means of addressing political impediments to higher tariffs over the long term. However, there are political obstacles that need to be overcome in order to establish independent regulation in the first place. The capacity for vested interests to undermine independent regulation is evident in both Africa (e.g., Mozambique) and the Pacific (e.g., Vanuatu, Fiji) [37,73,74]. Establishment of independent regulation also requires regulatory capacity that is not always available in Pacific SIDS. Financial support and technical assistance from development partners can assist in this area if delivered appropriately [36]. There is also potential for regional approaches to address issues of economies of scale that are specific to SIDS, although experience with regional services in the Pacific has been mixed [75].

Private sector participation and investment in the electricity sector is another area that could be further developed in Pacific SIDS. The private sector has the potential to provide much-needed experience and financing for rural electrification. But this will only occur if appropriate incentives are established. The removal of legislated monopolies for the provision of electricity by state-owned enterprises is a first step to encouraging private sector participation. Independent regulation can also ensure that fair prices are paid to concessionaires and independent power producers, thereby encouraging investment. This is already occurring in Fiji, Vanuatu, and Tonga.

Reform is necessary for both extension of the grid and off-grid rural electrification. The installation of off-grid systems is central to expanding electricity to rural populations given the geography and population distribution of Pacific SIDS. Institutional approaches that facilitate the sustainable operation and maintenance of installed systems need to be established. There are limits to government or donor-funded capacity building at the community level, given cost and poor transport infrastructure in many rural areas. An alternative approach involves the provision of electricity by the private sector, or cooperatives, with government subsidisation. Successful use of this approach in other countries has demonstrated the potential to leverage private sector investment and expertise. However, to succeed governments need to establish effective incentives for private sector entities. Political commitment to policy reform is required for this to occur.

Funding is also crucial for widening access to electricity in Pacific SIDS, both through extension of electricity grids and installation of off-grid systems. Private sector financing and user charges can reduce the fiscal burden, however, are unlikely to fund more than a small proportion of costs associated with rural electrification. Basic modelling undertaken for this paper suggests that funding requirements in Papua New Guinea and Solomon Islands are significant, although not beyond the capacity of governments to meet with support from development partners. But funding of rural electrification requires political commitment. Governments in Pacific SIDS currently prioritise service provision to urban areas; government subsidisation of existing electricity grids far outstrips funding for rural electrification across Pacific SIDS. The focus on renewable technologies in Pacific SIDS has in recent years contributed to the existing urban bias, with renewable energy targets leading to an emphasis on grid-based supply rather than rural electrification. It is necessary that governments and development partners re-prioritise rural electrification in order to improve access to power in the Pacific islands region.

5. Conclusion

Access to electricity in Small Island Developing States (SIDS) of the Pacific is limited by international standards. This has developmental impacts, with adverse consequences for economic development, household finances, and the health and education of rural households. Low levels of access to electricity in Pacific SIDS can in part be attributed to income levels, geography, and population distribution. The vast majority of un-electrified households in Pacific SIDS reside in rural areas, many on small islands separated from urban areas by the Pacific Ocean. This limits the potential to supply rural populations through the extension of power grids, and increases the importance of off-grid electrification relative to other developing countries.

Institutional arrangements in the electricity sector are also important. The extension of power grids into rural areas has been hindered in many Pacific SIDS due to limited commercial incentives and the poor financial health of power utilities. Electricity tariffs in many Pacific SIDS are below cost, for political reasons, limiting the ability of utilities to expand power grids. Power utilities as a result have no commercial incentive to expand electricity grids. Cross-subsidisation of power consumption in rural areas contributes to the lack of incentives to expand access, given that the connection of new areas commonly results in financial losses for power providers. Lifeline tariffs for households with low consumption have a similar impact when not reimbursed by government.

Reforms are needed to address these challenges. Experience among utilities in Pacific SIDS suggests that the establishment of independent regulators can help to ensure electricity prices (minus explicit government subsidies) reflect costs. Broader legislative changes that encourage private sector investment in electricity provision can also help alleviate the fiscal burden associated with grid extension. Political commitment is required. There is considerable institutional inertia and political resistance to power sector reform.

The installation of off-grid systems is also important for expanding access to rural electrification in Pacific SIDS. The sustainability of off-grid systems is a problem in most Pacific SIDS. Off-grid systems installed under government or donor-funded rural electrification programs are commonly not maintained, with systems failing as a result. The supply of electricity by a third party private sector operator (or cooperative) provides an alternative model. However, sound institutional arrangements that establish incentives for rural electrification among private sector companies are necessary for this arrangement to be successful. These arrangements will take time to develop.

Funding from government is needed to pay for the upfront cost of grid extension and off-grid electrification. In Pacific SIDS where access to electricity outside of urban areas is limited, funding requirements for rural electrification are significant. Governments will need to reverse the prioritisation of urban areas (and grid-based renewable technologies) over rural electrification in order to meet funding requirements. The emphasis of rural electrification programs on grid extension instead of installation of off-grid systems also needs to be reversed.

Two key requirements for expanding access to electricity in Pacific SIDS have been identified in this paper. The first is funding. Funding is crucial to rural electrification, whether through extension of the electricity grid or installation of off-grid systems. It is clear that funding for rural electrification in Pacific SIDS with large un-electrified populations is not adequate. This needs to be addressed, through leveraging private sector investment, collection of appropriate user fees, and increased public funding (which can be made available by reducing subsidies for power consumption that benefit high and middle income households). The second requirement for expanding access to electricity in Pacific SIDS is the reform of institutional arrangements. Reform is necessary for establishing incentives to extend electricity grids. It is also needed in order to ensure that off-grid systems that are installed remain in a workable condition. Progress in expanding access to electricity in Pacific SIDS will remain slow until these two requirements are met.

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